ACPC Initiative to Identify Signatures of Aerosol-Cloud Interactions in High-Resolution Modeling and Observations

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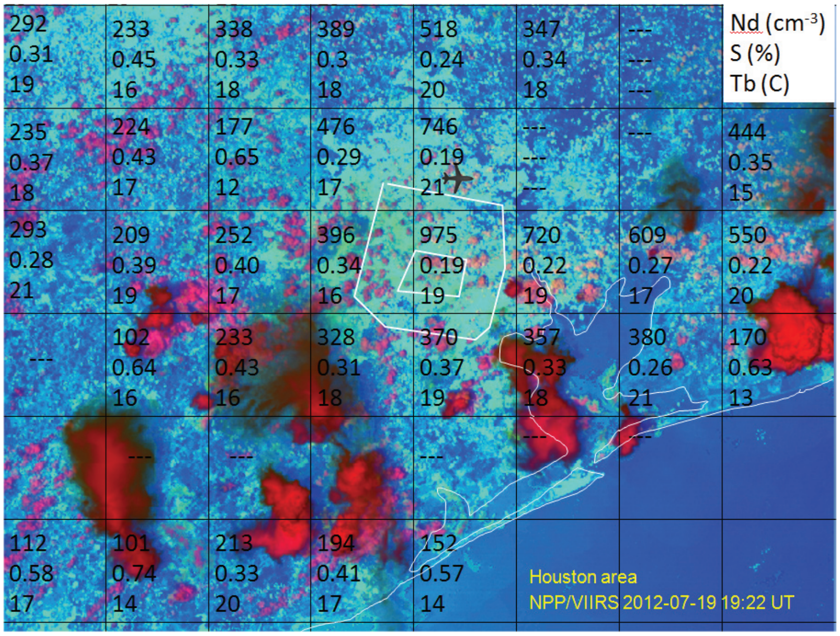
The goal of the Aerosols-Clouds-Precipitation-and-Climate (ACPC) Initiative is to assess processes involving aerosol-cloud-precipitation interactions. The current ACPC science approach follows the recommendations from its first phase (Rosenfeld et al., 2014), using a hierarchy of models to assess the observational requirements for a quantitative understanding of the impact of aerosol perturbations on clouds given the dominant influence of variable meteorological conditions on cloud and precipitation properties. The working hypothesis is that such a modeling approach becomes feasible when simulating domains and time periods that cover the full life cycle of cloud systems in time and space using cloud-resolving models that account for the two-way interaction of aerosols with clouds and precipitation.

At last year's annual ACPC workshop held in New York, it was decided that ACPC would pursue separate studies for a shallow cloud regime and a deep convective cloud regime. Two cases were selected, namely marine stratocumulus clouds off the west coast of South America as observed during the Variability in the American Monsoon Systems (VAMOS) Ocean-Cloud-Atmosphere-Land Study (VOCALS) field campaign from mid-October to mid-November 2008, and deep convective clouds in the area of Houston, Texas in August and September 2013. The approaches for investigating impacts of aerosol perturbations differ for the two cases.

For the deep convective case, cloud condensation nuclei (CCN) concentrations derived from satellite data were used to identify the CCN perturbation from Houston, Texas in the otherwise unpolluted onshore flow. This perturbation yielded an augmentation of near-surface CCN concentrations by a factor of 5–10 (see figure on next page). The group investigating this case is working on the hypothesis that a perturbation in deep convective cloud processes may become detectable when microphysical signatures in retrievals from polarimetric radar and lightning networks for perturbed vs. unperturbed clouds are statistically analyzed. To the extent that such differences are matched by the results from different models, the understanding of how aerosols and deep convective clouds interact may be enhanced. For the shallow cloud case, the first objective is to explore the spatial gradient in aerosol concen-



Analysis of satellite data to infer cloud condensation nuclei concentrations. Much higher CCN concentrations are retrieved in the air masses impacted by the Houston emissions. ACPC will analyze high-resolving model results and NEXRAD radar observations to investigate the possible impacts of the elevated CCN concentrations on convective clouds for this and other similar cases. The color scheme is microphysical RGB, where red is modulated by the visible reflectance, green by 3.7 µm solar reflectance, and blue by thermal temperature. After Rosenfeld et al., 2016).

trations and assess the covariability of aerosol concentrations and cloud properties, in comparison to satellite data and in situ observations from the VOCALS campaign. The group is currently assessing the extent to which aerosol-cloud interaction metrics (Feingold, 2003) can be useful for determining aerosol-cloud interaction processes, and for evaluating these in models. The challenge is to analyze cause-effect relations on the basis of aerosol and cloud covariability and to account for measurement uncertainties. Joint histograms rather than scalar linear regression coefficients may be a useful alternative (Gryspeerdt et al., 2016). Secondly, in the regional models, a perturbation of the aerosol emissions is performed to assess the extent to which the cloud fields and aerosol-cloud interaction processes differ in a perturbed scenario. First results from the University of Leeds and the UK Met Office at a horizontal resolution of 1 km (see figure on next page) suggest that a strong reduction in aerosol concentrations leads to a simulated cloud liquid water path distribution that is inconsistent with the observations. In turn, an increase in aerosol concentrations even by an order of magnitude yields results that are almost indistinguishable from the control simulation. In addition to exploring the behavior of regional models (which range from non cloud-resolving to marginally cloud-resolving), the group will also use the regional models to drive Lagrangian large eddy simulations (LES) of aerosol-cloud evolution. The behavior of the LES can be compared with those from the regional models to ascertain the extent to which the regional models are skillfully capturing the key interactions between aerosols and clouds required to accurately constrain the indirect radiative forcing. The analysis of LES will also help to assess influences of parameterizations and model resolution.

It was decided at the annual ACPC workshop held in April 2016 at the University of Oxford to continue working on these two cases, which will serve to provide guidance to aid the planning of future field experiments designed to better constrain the aerosol influence on regional clouds and climate.

The group is also very interested in other ongoing and planned field campaigns. Several contributors to ACPC are involved in these campaigns, especially in the Observations of Aerosols above Clouds and their Interactions (ORACLES) and Cloud-Aerosol-Radiation Interactions and Forcing (CLARIFY) projects that investigate aerosol-cloud-radiation interactions off the coast of Southern Africa; the Southern Ocean Clouds, Radiation, Aerosol Transport Experimental Study (SOCRATES) and the Antarctic Circumnavigation Expedition: Study of Preindustrial-like Aerosol-Climate Effects (ACE-SPACE) campaigns aimed at targeting the southern ocean clouds; and the Aerosol-Cloud-Experiments over the Eastern North Atlantic (ACE-ENA) aircraft campaigns. In addition, there was particular interest in the Cloud and Aerosol Monsoonal Processes-Philippines Experiment (CAMP2Ex), which examines a region where distinct, very large aerosol perturbations occur, and in the Elucidating the Role of Cloud-Circulation Coupling in Climate (EUREC4A) campaign, since it aims at a comprehensive characterization of the large-scale budgets. Along with these field campaigns, ACPC is also interested in the results from modeling studies that several participants contribute to, such as high-resolved simulations with perturbed aerosol for the Convective Precipitation Experiment (COPE) cases over Southwest England performed by the team at the University of Leeds and UK Met Office, various model intercomparison studies in the EU project "Impact of Biogenic versus Anthropogenic emissions on Clouds and Climate: towards a Holistic UnderStanding" (BACCHUS), and a perturbed-aerosol simulation over Germany from the High Definition Clouds and Precipitation for Climate Prediction [HD(CP)^2] project.

In the coming year, our goal is close collaboration within the modeling teams. This will involve the generation of compatible model diagnostics of observable quantities and the joint assessment of aerosol, cloud and precipitation variability for the two cases. The observational analysis will specifically address options to improve satellite retrievals of relevant quantities (in particular cloud droplet concentrations), and to better exploit and couple the innovative observations by satellites and polarimetric radar.

Finally, a new GEWEX Global Aerosol Precipitation (GAP) initiative was presented at the workshop. The overarching goal of GAP, which is co-chaired by Sue van den Heever and Philip Stier, is to provide a global-to-regional assessment on the impacts of aerosol on precipitation, complementing ACPC's process-focused activities. GAP will seek to work collaboratively with ACPC, as well as all four GEWEX Panels on aerosol-precipitation interactions.

The next ACPC workshop is planned for 2–6 April 2017 in Bad Honnef, Germany. Interested persons are welcome to join the activities.

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BACCHUS: *http://www.bacchus-env.eu/*

CAMP2Ex:
https://espo.nasa.gov/missions/sites/default/files/documents/CAMP2Ex-overview-27NOV2015.pdf

CLARIFY: *http://blogs.exeter.ac.uk/clarify2016/*

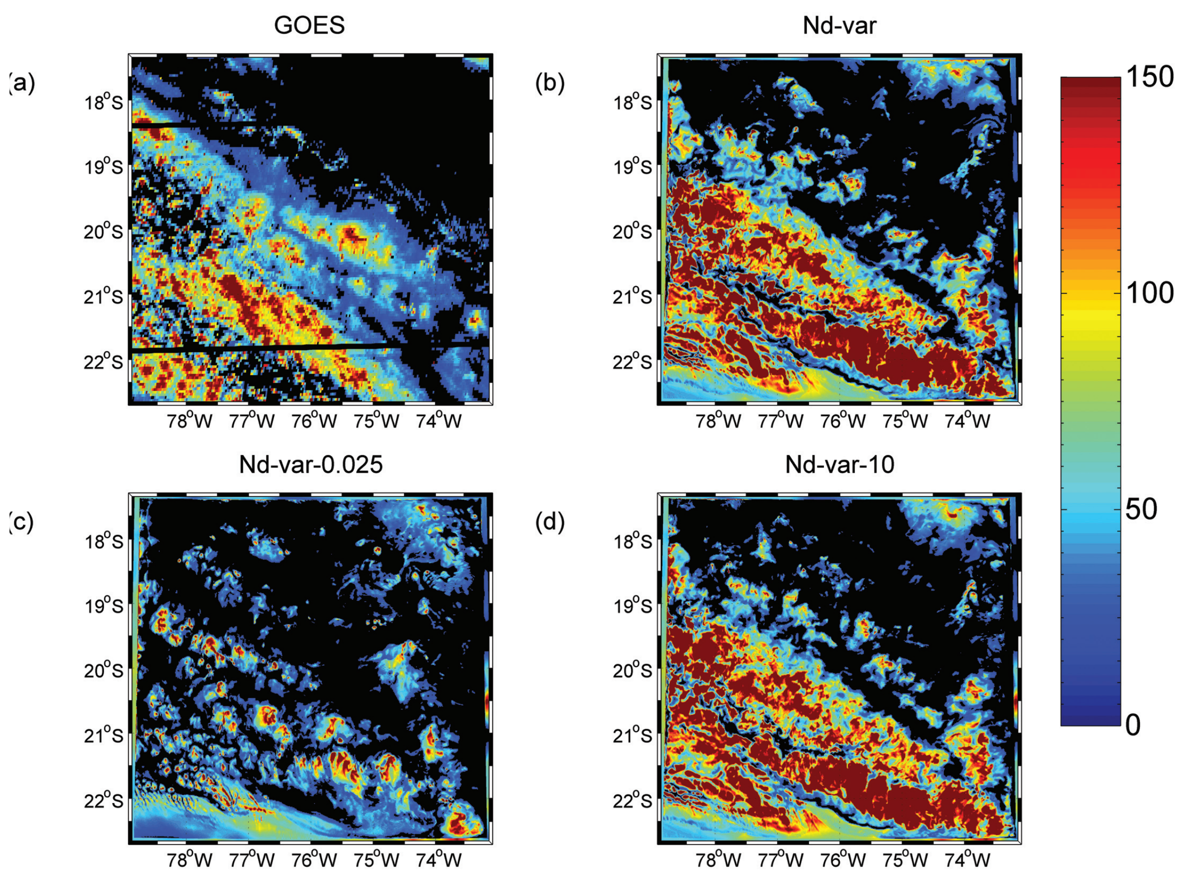
EUREC4A:
http://www.mpimet.mpg.de/en/science/the-atmosphere-in-the-earth-system/narval-eurec4a/

HD(CP)²: *http://hdcp2.eu*

ORACLES: *http://science.nasa.gov/missions/oracles/*

SOCRATES: *http://www.atmos.washington.edu/socrates*

VOCALS: *https://www.eol.ucar.edu/projects/vocals/rex.html*



Simulation of the VOCALS case using the UK Unified Model including the aerosol scheme CASIM. The cloud liquid water path (g/m²) is shown in comparison to satellite retrievals from the GOES satellite. In two sensitivity simulations, the aerosol concentration is reduced by a factor of 40, and augmented by a factor of ten. Results from Daniel Grosvenor (University of Leeds), Paul Field, Adrian Hill and Ben Shipway (UK Met Office, Exeter).